A Fifteen Year Study of Phytoplankton Biomass and Composition in the Nanticoke Region of Long Point Bay Lake Erie

July 1985

Ministry of the Environment
Ontario

A fifteen year study of phytoplankton biomass and composition in the Nanticoke region of Long Point Bay Lake Erie

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Running Head: Fifteen year study of Lake Erie phytoplankton

Key index words: algae, Lake Erie, Nanticoke, phytoplankton biomass

PREFACE

Since the establishment of the Nanticoke Environmental Committee in 1968, phytoplankton monitoring has been conducted during the ice-free period of each year in the vicinity of the Nanticoke thermal generating site in Long Point Bay, Lake Erie. Three interim reports have been prepared describing the phytoplankton conditions at Nanticoke from 1969 to 1978. This report was prepared to provide a summary of these conditions for the fifteen year period 1968 to 1983. This report is the phytoplankton component to the Integrated Nanticoke Report being prepared by the Nanticoke Environmental Committee.

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ABSTRACT

Changes in abundance, taxonomic composition and the seasonal succession of phytoplankton have been evaluated at seven stations in the vicinity of Nanticoke, east of Long Point Bay, Lake Erie from 1969 to 1983. No phytoplankton samples were collected in 1979. Quantitative measurements of phytoplankton were recorded as Areal Standard Units per millilitre (A.S.U. per mL). The 14-year mean value was 401 A.S.U. per mL. Annual means over the 15 year period varied from a low of 224 A.S.U. per mL in 1969 to a high of 606 A.S.U. per mL in 1978.

Seasonal succession patterns and biomass levels showed fluctuation expressing unimodal, bimodal and even trimodal peaks from station to station and year to year. 1969 and 1974 had abnormally low levels of phytoplankton biomass while 1970 and 1978 showed mean biomass values that were exceptionally higher than the 14-year mean. A total of 255 taxa were recorded during the 15 years of study, 35 of which were present during all years.

Temperature data collected at the same stations suggested that 1970 and 1973 were years in which the water was slightly warmer but followed very closely a normal seasonal curve ranging from 5°C in April to a maximum of 22°C in August. A comparison of seasonal succession of phytoplankton to temperature did not show any direct or inverse relationship to years in which one or the other parameter deviated from the normal pattern.

Due to the similarity of the algal community in its year-to-year seasonal development and taxonomic composition, the fourteen years of data presented in this study should provide a sound data base for future comparisons on nearshore phytoplankton in Lake Erie.

INTRODUCTION

Previous studies of Lake Erie phytoplankton, while numerous, have been concentrated in the offshore waters of the western and central basins until recently. Five studies conducted in the eastern basin of Lake Erie since 1967 by different Canadian and American agencies have been identified by Nicholls (1981). These studies were initiated to provide baseline data on phytoplankton for water quality assessments and to detect changes in the trophic status of Lake Erie's eastern basin.

Phytoplankton monitoring carried out during the past 15 years and reported in this paper was initiated to provide information on seasonal and long term fluctuations in algal biomass in the nearshore regions of Long Point Bay and to detect any changes due to thermal and/or industrial inputs from the developing industrial complex at Nanticoke on the north shore of Lake Erie's eastern basin. The Nanticoke Environmental Committee (N.E.C.) consisting of industrial and government representatives was established in 1968 to conduct studies of the aquatic environment in Long Point Bay, Lake Erie, (Jeffs 1981). Construction of a 4400-MW thermal generating station by Ontario Hydro, a modern integrated steel mill by the Steel Company of Canada (Stelco) and an oil refinery by Texaco Canada Ltd., have been initiated since 1968.

Facilities at Ontario Hydro were operational by 1972 but by 1974 were only operating at 13% capacity and by 1978 were still at less than 50% capacity. The Texaco refinery did not come into operation until October, 1978 and the Stelco plant was not to be operational until the spring of 1980. Construction operations such as docking facilities and underwater pipeline structures for water

supply and waste caused only temporary disruption to the aquatic environment so that the period 1968 to 1978 is considered to be pre-operational. Data collected from 1980 to 1983 should reflect conditions of active industrial operations.

As part of the aquatic environmental studies in this pre-operational period, phytoplankton surveys have been conducted during the ice-free period of each year at fixed locations in the Nanticoke vicinity of Long Point Bay. Some of the findings of these studies have been reported by Michalski (1972), Hopkins (1975), Hopkins (1979), Hopkins and Lea (1979), and Hopkins and Lea (1982).

METHODS

In a reconnaisance survey conducted in 1967 a sampling grid for chemical analyses was established with collections taken at the surface, mid-depth and one metre off the bottom at each location. Initially, phytoplankton samples were collected at the same sample depth as chemical samples but by 1972 samples for phytoplankton analyses were collected as photic zone composites (Table 1). This was achieved by lowering and raising a one litre narrow-necked bottle through the photic zone portion of the water column which was established at twice the Secchi disc depth or to within one metre of the bottom (whichever was shallower). This paper includes the seven stations for which data are available for all 15 years of the study, namely stations 112, 501, 518, 648, 810, 994 and 1016 (Fig. 1). No phytoplankton samples were collected in 1979. Samples were not collected from stations 501, 518 and 648 in 1980. Stations were located in 5 to 8 meters of water at a distance of 0.5 km to 2.5 km from shore along approximately 10 km of shoreline in the vicinity of the area to be developed as an industrial complex.

All samples (1 litre in size) were preserved with Lugol's iodine solution at the time of collection. In the laboratory, part of each sample was concentrated to a final volume of 25 mL by sedimentation. This 25 mL concentrate was retained for future analyses and subsequently a 1 mL aliquot was transferred into a Sedgwick-Rafter cell for counting using a compound microscope at 200X magnification prior to 1975. Most of the algal forms were identified at least to the genus level but small chrysomonads, cryptomonads and chlorococcalean algae were examined at 450X or 600X magnification. Chrysochromulina, the only member of the prymnesiophyceae which we routinely encounter was grouped with the Chrysophyceae (Table 4) only for convenience. Slides prepared with Hyrax mounting medium were used to facilitate the identification of diatoms. Since 1975, we have phased in the use of inverted microscopes so that by 1980 all of the samples were analyzed using the inverted microscope at 600X magnification.

Phytoplankton biomass has been expressed as Areal Standard Units per mL (A.S.U./mL) throughout the 15 year period of study. One Areal Standard Unit is the area subtended by 400 μm^2. The A.S.U. method has been used in conjunction with the Sedgwick-Rafter counting cell (A.P.H.A. 1960) and was adopted by the Ministry of the Environment (formerly O.W.R.C.) for monitoring phytoplankton densities in water supplies and Great Lakes water quality studies in the early 1960's. For comparative purposes average algal densities have been reported as both A.S.U./mL and mm^3/L (Table 2).

RESULTS AND DISCUSSION

Studies of the aquatic environment, including biological, chemical and physical characteristics have been undertaken by N.E.C. participants since 1967. Data on water temperature, water movement, water chemistry, fish, bottom fauna, zooplankton, attached algae and phytoplankton have been reported annually for each parameter and summarized collectively in three integrated reports (N.E.C. 1973, 1978 and 1984). Data from the individual reports are available as microfiche from the Ontario Ministry of the Environment.

Biomass

With phytoplankton data available from seven stations during the ice-free period for fourteen years it was possible to develop long term seasonal averages and determine if there was any significance to the annual variations in this pattern. Table 3 provides a summary of the mean phytoplankton densities for the seven stations by date for the years 1969 to 1983. Low values of 99 A.S.U. per mL on June 30, 1969, 77 A.S.U. per mL on May 5, 1974, 62 A.S.U. per mL on June 22, 1976 and 94 A.S.U. per mL on July 7, 1982 were recorded. High values of 1377 A.S.U. per mL on September 22, 1970, 1083 A.S.U. per mL on August 7, 1973 and 1231 A.S.U. per mL on August 30, 1978 and 1070 A.S.U. per mL on August 23, 1983 were recorded. The highest values of 1377 A.S.U. per mL on September 22, 1970 was caused by high densities of *Aphanothece* spp. The 1978 high was caused by a diatom pulse of *Fragilaria crotonensis* Kitt. and *F. capucina* Desm.

From Table 3, data in the odd numbered weeks 15 to 49 were compared to the even numbered weeks 16 to 50 between 1969 and 1983. There was no significant difference in the two data sets

(T-test; $P < 0.05$); therefore, the two data sets were combined to show the seasonal development of phytoplankton growth by plotting the fourteen year monthly means (Fig. 2). A comparison of the differences between the fourteen year average and the seasonal abundance (monthly mean) for each year indicates no consistent pattern of differences with time in any part of the seasonal cycle (Fig. 3). In 1974 the spring pulse and the summer minimum were lower than "normal". In 1970 a growth of the blue-green *Aphanothece* spp. caused an exceptionally high biomass peak in September. In 1978 phytoplankton abundance was much higher than normal in all months except April and September. A late spring pulse of *Fragilaria* spp. was responsible for much of the increase in the 1978 annual mean. In 1981 and 1982 the summer minimum occurred on July 7th dominated by the cryptophyte, *Cryptomonas* in 1981 and the prymnesiophyte *Chrysochromulina parva* in 1982. In 1983 a seasonal high in August was caused by the co-dominance of a number of green algae and the blue-green *Aphanothece*.

The annual mean phytoplankton biomass is shown in Fig. 4. Average biomasses for the seven stations during 1969, 1972 and 1974 were unusually low while 1970, 1978 and 1983 were exceptionally high. Annual mean biomasses from 1980 to 1983 were slightly higher than the 14-year mean of 401 A.S.U. per mL. However, this kind of fluctuation is not unusual with a biological population and is balanced between the lows and highs during the other seven years. For the seven stations included in this study the lowest annual mean phytoplankton biomass at Nanticoke was recorded in 1969 (244 A.S.U. per mL or .59 mm^3/L) and the highest value was recorded in 1978 (606 A.S.U. per mL or 1.39 mm^3/L). The third highest biomass (524 A.S.U. per mL or 1.22 mm^3/L) was recorded in 1970 during the second full year of the study.

Until recently there have been very few phytoplankton studies conducted in the eastern basin of Lake Erie. Munawar and Munawar (1976) reported that phytoplankton biomass ranged between 1.0 and 4.2 mm^3/L with a seasonal mean of 2.4 mm^3/L for seven stations in the eastern basin in 1970. The seasonal distribution of algae was quite similar to our studies with Cryptomonas erosa Ehr. and Rhodomonas lacustris Pasch. et Ruttner (Syn. R. minuta Skuja) appearing as perennial species while diatoms dominated during spring and late fall. A 1970 late summer pulse of blue-greens in the near-shore region of the eastern basin was noted by Munawar and Munawar (1976). A blue-green pulse dominated by Aphanothece spp. was reported in our studies for the same year.

Studies conducted in the eastern basin of Lake Erie from 1973 to 1976 by State University College at Buffalo (S.U.C.B.) showed remarkable similarities to the present study both in biomass and taxonomic composition (V.R. Frederick, unpub. data). S.U.C.B. stations 13 and 80 were in the vicinity of Nanticoke stations 112 and 501. In early July, 1973 the cryptophytes, Cryptomonas erosa and Rhodomonas lacustris represented 55% and 85% of the algal biomass at the S.U.C.B. and Nanticoke stations respectively. During S.U.C.B. cruise IV (May 21 to June 1, 1974) cryptophytes represented 65% of the total biomass and continued to dominate the algal flora through cruises VI and VIII (July 26-30). At the same time data from the Nanticoke study indicated a dominance by the same cryptophytes from late May to the end of July with a 62% representation on June 4, 1974. In late August, 1974 Aphanothece nidulans P. Richter accounted for 50% of the biomass at the S.U.C.B. stations and 60% of the biomass at the Nanticoke stations. Both

studies indicated that in 1973, 1975 and 1976 the Cyanophyta did not attain late summer peaks but that the Chlorophyta were more prominant in late summer and fall in 1975 and 1976. In 1975 the annual mean biomass for the S.U.C.B. cruises was 0.68 mm^3/L while at Nanticoke the annual mean biomass was 0.93 mm^3/L. In 1976 a similar seasonal succession of algae was reported at Nanticoke and by the S.U.C.B. study (V.R. Frederick, personal comm.). Fragilaria crotonensis was reported by both groups as being an important taxon in early August, 1976 at a time when in previous years the diatoms were usually insignificant. The annual mean algal biomass reported by S.U.C.B. and at Nanticoke in 1976 was 1.2 mm^3/L and 0.77 mm^3/L respectively.

Seasonal Succession and Species Composition

The seasonal succession of algal abundance (Fig. 2) was comprised of an early spring peak followed by an early summer minimum and then an annual maximum which lasted from the middle of July to the middle of September after which there was a steady decline to the annual minimum in late November and early December. This seasonal succession of algal abundance was characterized by diatoms and cryptophytes in the spring, cryptophytes and greens in early summer, followed by blue-greens in late summer and reverting back to cryptophytes and diatoms in the autumn. Michalski (1972) reported that Stephanodiscus sp., Fragilaria crotonensis, Cryptomonas erosa and Rhodomonas lacustris were the most prominant algal forms observed from 1969 to 1972 (Table 2).

Hopkins (1975) reported that the bimodal pattern of algal development described by Michalski (1972) was present in 1972 but was not evident in 1973 and 1974 when a unimodal peak occurred in

August, represented at most stations by Fragilaria crotonensis and Rhodomonas lacustris. This was followed in both years by a rapid change to an almost exclusive population of blue-green algae later in the summer and during early autumn. From 1975 to 1978 there was a return to the more typical bimodal pattern of algal development. In 1978, however, a massive development of Fragilaria crotonensis (80% of biomass) in June, followed by Cryptomonas erosa in July, Aphanothece in late August and Fragilaria spp. and Stephanodiscus in late October obscured this bimodal pattern.

While no samples were collected for phytoplankton analyses in 1979, sampling was resumed in 1980 at four of the seven stations reported in this study, namely stations 112, 810, 994 and 1016. From 1981 to 1983 samples were collected 17 to 20 times each season between mid-April and early December. Seasonal succession followed a bimodal pattern each year with a dominance of the diatoms Stephanodiscus and Fragilaria each spring and fall. This was followed in succession by a period in May that was dominated by the Chrysophyceae, a period in June and July during which the cryptophytes, Rhodomonas and Cryptomonas were dominant. This corresponded to the seasonal minimum in algal biomass. During August and early September the Chlorophyceae and Cyanophyceae became dominant or were co-dominant. The 1981 and 1982 pattern of seasonal succession was remarkably similar. In 1983, however, the green algae that developed in late July lasted until mid-October when they were replaced by the diatoms which as in previous years dominated at all stations until the end of the sampling season in December.

An examination of the taxonomic composition of the phytoplankton revealed a total of 255 taxa (Table 4) during the fifteen years of study. The Chlorophyceae and Bacillariophyceae

groups were represented by 107 (42%) and 66 (26%) taxa, respectively. The Cyanophyceae and Chrysophyceae groups represented by 32 and 33 taxa (13% each) were next while the Dinophyceae and Cryptophyceae were represented by 8 and 7 taxa (3% each). Euglenophyceae with 3 taxa represented less than 1% of the taxa observed during the study period. While the Chlorophyceae were represented by the greatest number of species, the diatoms, cryptophytes and blue-greens presented the greatest biomass. Thirty-five taxa were present in all years of the study while seventy-one were present during six or more years. In 1970 extra effort was placed on taxonomy at which time 169 taxa were recorded, 101 of which were determined to species.

While temporal patterns and taxonomic composition were similar from year to year, the study area was also examined for spatial differences. Michalski (1972) reported on near-shore and off-shore differences in the phytoplankton community from 1969 to 1971. However, as the seven stations are all within 5 kilometers of shore and in less than 10 metres of water they are all considered as nearshore stations for the purpose of this report. Statistical analyses performed by Polak (1978) and by Heathcote (1979) indicated that up to 1977 there were no spatial differences in the phytoplankton and that there was no statistically significant trend with time from 1969 to 1977. With the addition of the 1978 phytoplankton data there was a change in the long term trend indicating a small statistical increase of ≈4% per annum over the ten year period. When the phytoplankton values for the 1980-1983 period are included in the data set the long-term trend, while not statistically significant ($r = 0.486$; $P < 0.05$) continued to show an approximate 4% per annum increase. Weiler and Heathcote (1979), in

examining the water chemistry at Nanticoke indicated that for most parameters the area were spatially homogeneous. Farooqui and Christensen (1980) also found that the area was spatially similar in their study on water temperature.

Phytoplankton-Water Temperature Relations

One of the most important environmental factors affecting phytoplankton growth is temperature. Most algae have an optimum temperature for growth and if this temperature is not reached or is exceeded then growth will be curtailed. The Nanticoke area of Lake Erie is typical of deep lakes in the North Temperate climatic zone where the temporal pattern of phytoplankton development is usually bimodal with minimum densities in winter and midsummer and maximum densities occurring as vernal and autumnal pulses. The temperature regime at the time of these maximal pulses according to McCombie (1953) ranges from 14°C to 20°C and, with the exception of some blue-green algae, temperatures greater than 25°C may be inhibitory to algal growth. While the monthly mean values may have obscured the vernal pulse it may be seen from Figure 2 that the maximum phytoplankton growth at Nanticoke occurred during August and September when the monthly mean temperature was 21.5 and 19.2°C respectively. Moore (1976) stated that _Cladophora_ had an optimal growth temperature of ≈20°C in the Nanticoke region and that temperatures approaching 25°C became inhibitory.

Ontario Hydro has summarized the water temperature data from the Nanticoke area at five permanent locations and has temperature profiles covering the entire fifteen year period for the seven stations included in this report (Farooqui and Christensen, 1980 and Farooqui, personal communication). Raw temperature data from the two

metre depth at each of these seven stations (except in 1979 and 1980 when only four stations were used) was selected as that which would be most closely associated with the photic zone depth from which the phytoplankton samples were collected. Comparable 2 metre temperature data from the Stelco site and Peacock Point (Fig. 1) were selected by Farooqui and Christensen (1980) to represent local ambient conditions. Temperature data from the seven stations (2 metre depth location) were analysed in the same manner as the phytoplankton data. Comparison of data from the even weeks 16 to 50, with the odd weeks 15 to 49 indicated no significant difference in the two data sets (T-test; $P < 0.05$), (Table 5). These data were then combined to provide a seasonal pattern (monthly mean) for the fifteen year period (Fig. 2). As with the phytoplankton, a comparison of the monthly mean in each year to the average seasonal mean showed no consistent pattern or trend with time in any part of the seasonal cycle (Fig. 5). It may be seen from Figure 5 that, (with 9 exceptions), data for all years falls within ± 1 S.D. of the long-term monthly mean (i.e. November, 1976 -3.6°C or -41% is >1 S.D.). The maximum monthly mean temperature recorded for all stations reported by Farooqui and Christensen (1980) was 23.9°C at Peacock Point and Woods Point in 1970. It is interesting to note that this corresponds to the year of maximum annual mean phytoplankton density between 1969 and 1977 (Fig. 4). It was reported by Hopkins and Lea (1982) that water temperatures were marginally warmer in 1970 and 1973. With the addition of data collected from 1979 to 1983 the years 1980 to 1983 may also be marginally warmer. The month of May shows a small significant increase ($r = .534$; $P < 0.05$) with time. There was no positive

or inverse relationship between years when phytoplankton growth and/or temperature deviated from the long term seasonal pattern of development. Water temperatures of approximately 20°C during mid-summer can be considered "normal" for the Nanticoke area and changes of a few degrees over a few days would be unlikely to have any important effects on the seasonal succession of phytoplankton.

CONCLUSIONS

This study has shown that in most of the fifteen years a weak bimodal seasonal cycle of phytoplankton abundance with a small spring pulse and maximum values in late summer followed more or less the seasonal temperature cycle. Annual variations in temperature and biomass were slight with most years consistently within the confidence limits with the exception of 1970, 1978 and 1983 which were above average and 1969, 1972 and 1974 which were below average. There was no consistant trend in the yearly or monthly means of phytoplankton abundance. The seasonal development by groups of algae was masked somewhat in the years of high abundance by *Aphanothece* spp. (in 1970) and by *Fragilaria* spp. (in 1978). There was a relatively high diversity of algae present as indicated by the 255 taxa listed for the seven sites during the fifteen years of study. Some taxa were present as dominants in almost all years with some species becoming most abundant for short periods of time.

The fifteen years of phytoplankton data from the Nanticoke area of Lake Erie have shown that there have been no important changes during the study period. Year-to-year differences in seasonal periodicity, taxonomic composition and biomass have been

only slight. Complementary studies on the water temperature and water chemistry are supportive of these findings. The phytoplankton data presented here should provide a valuable basis for future studies of the nearshore area of Lake Erie.

ACKNOWLEDGEMENTS

We would like to thank Mr. K. Nicholls for his guidance in preparing this paper; R. Farooqui, Ontario Hydro, for temperature data; and Mrs. M. Barclay for typing the manuscript.

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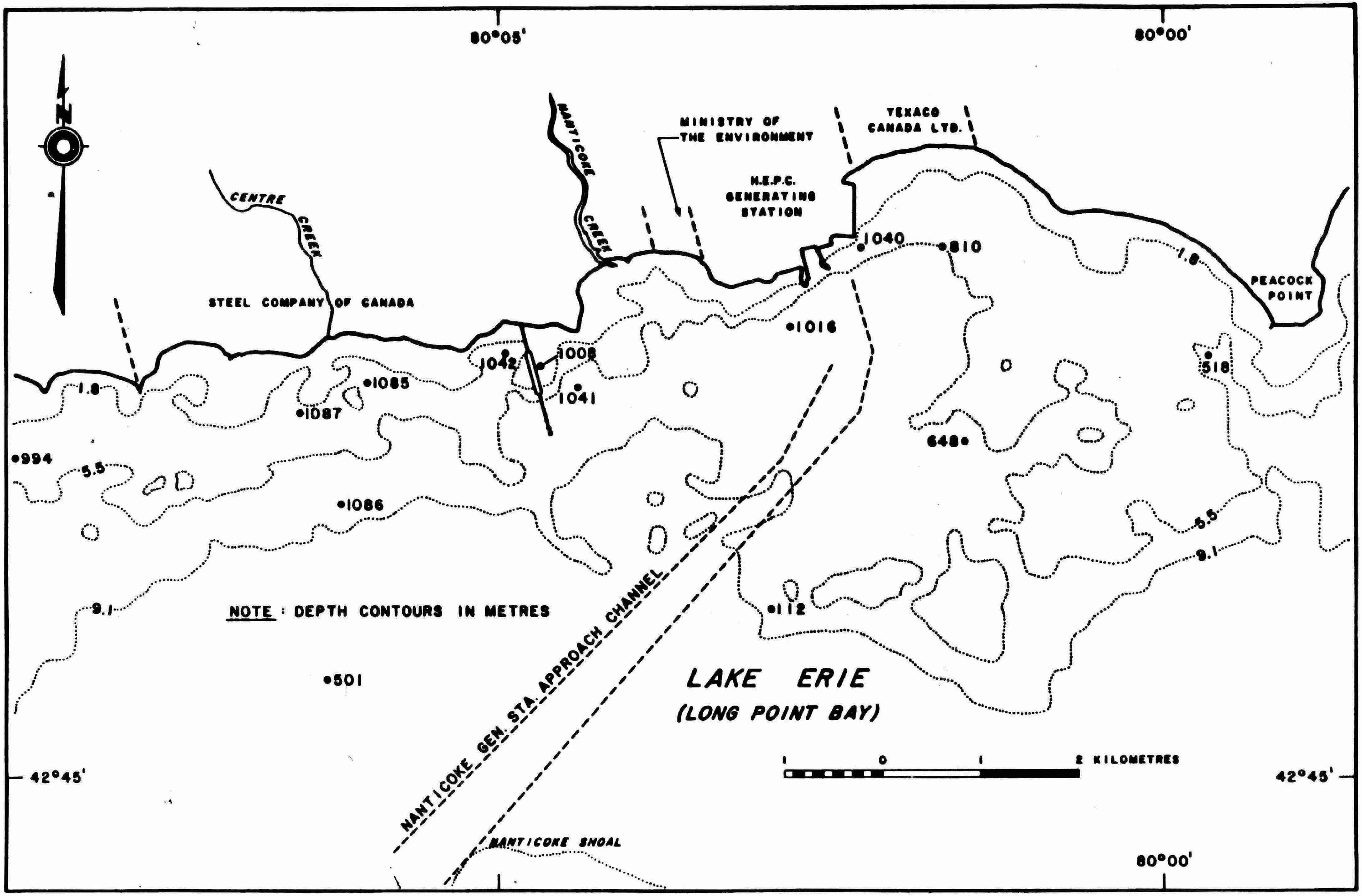


FIGURE I – NANTICOKE SAMPLING STATIONS (M.O.E.)

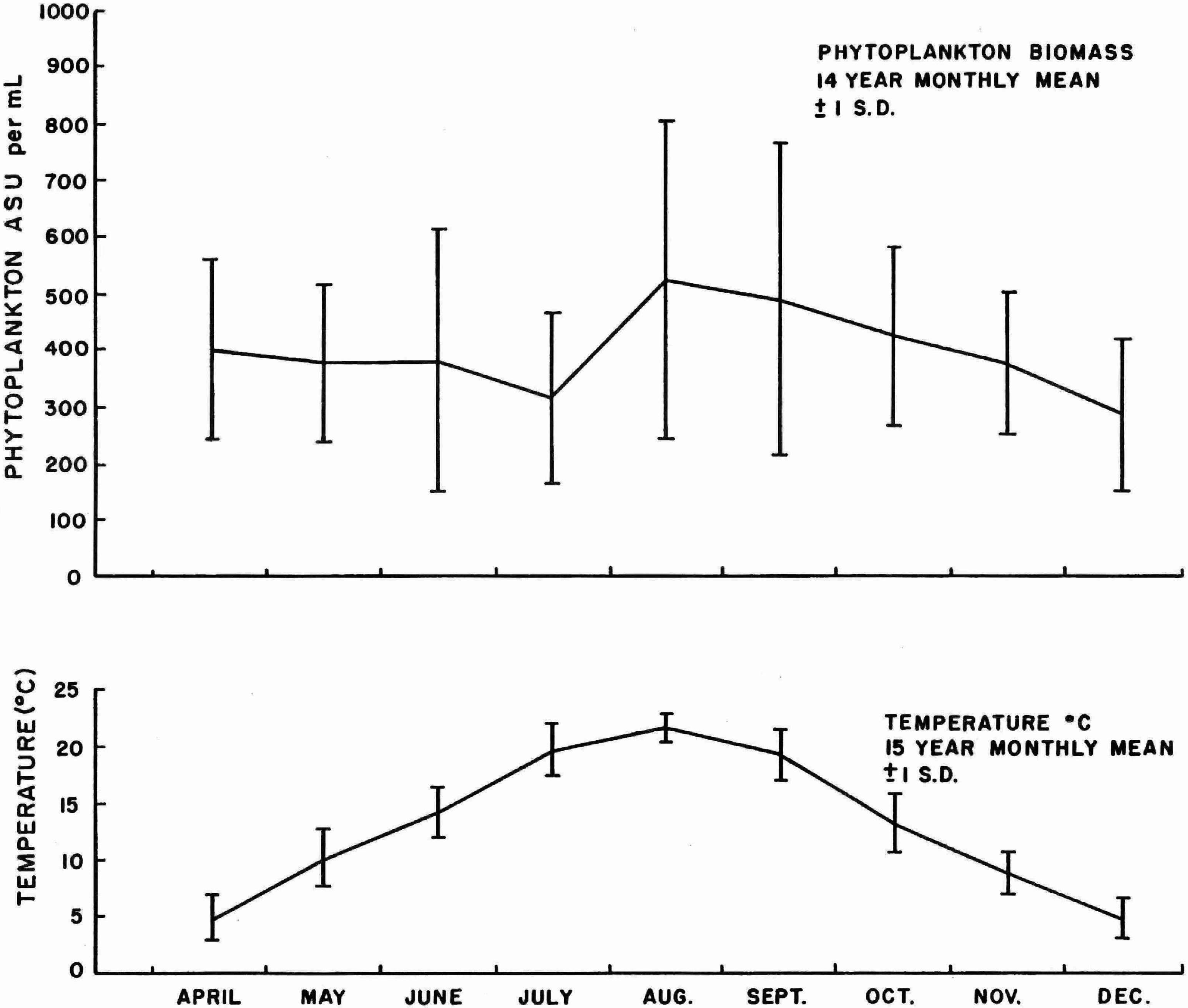

PHYTOPLANKTON BIOMASS
14 YEAR MONTHLY MEAN
± 1 S.D.
PHYTOPLANKTON ASU per mL
1000
900
800
700
600
500
400
300
200
100
0
TEMPERATURE °C
15 YEAR MONTHLY MEAN
± 1 S.D.
TEMPERATURE (°C)
25
20
15
10
5
0
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

FIGURE 2

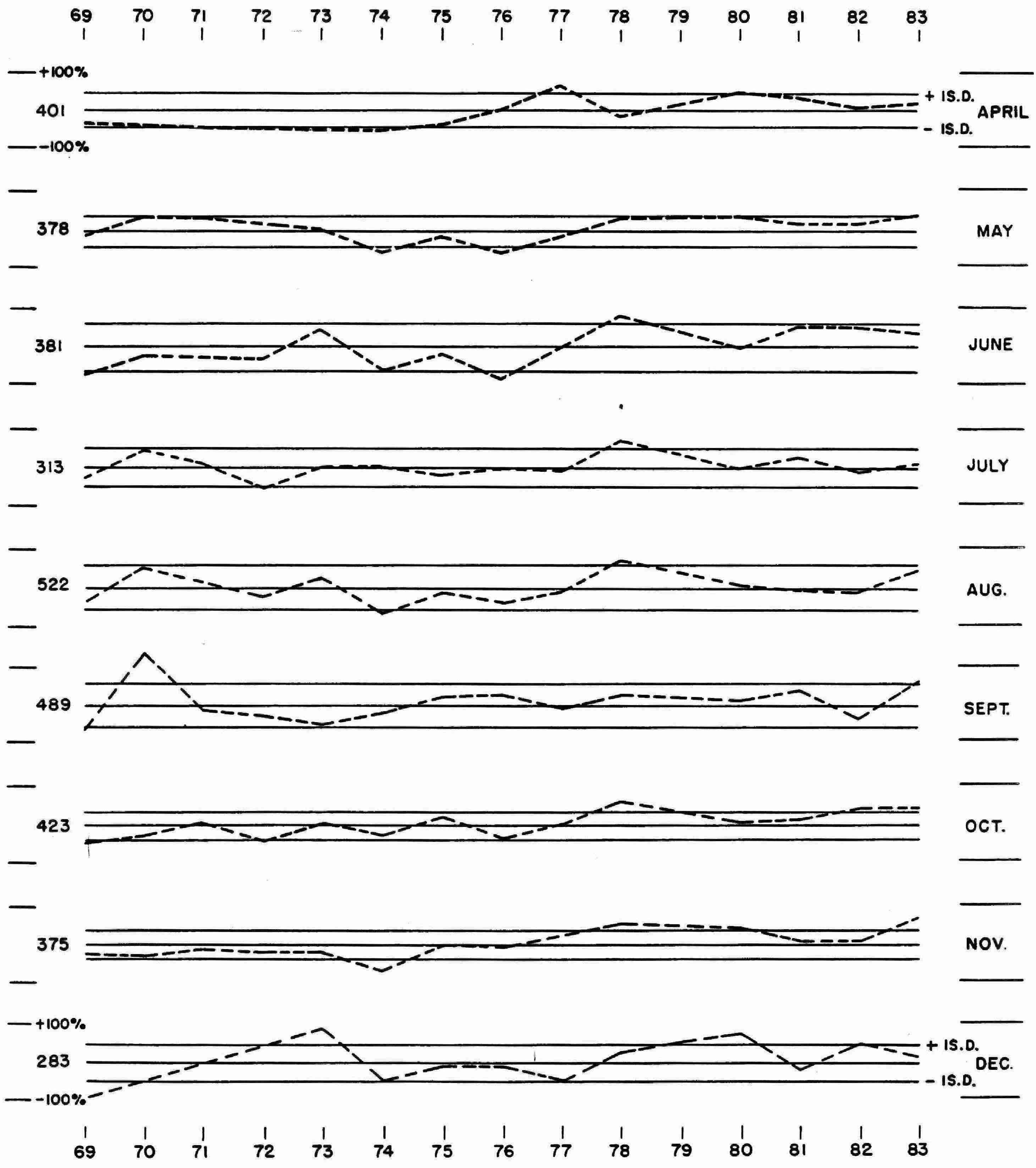

69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
+100%
-100%
401
378
381
313
522
489
423
375
283
+ IS.D.
- IS.D.
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

FIGURE 3

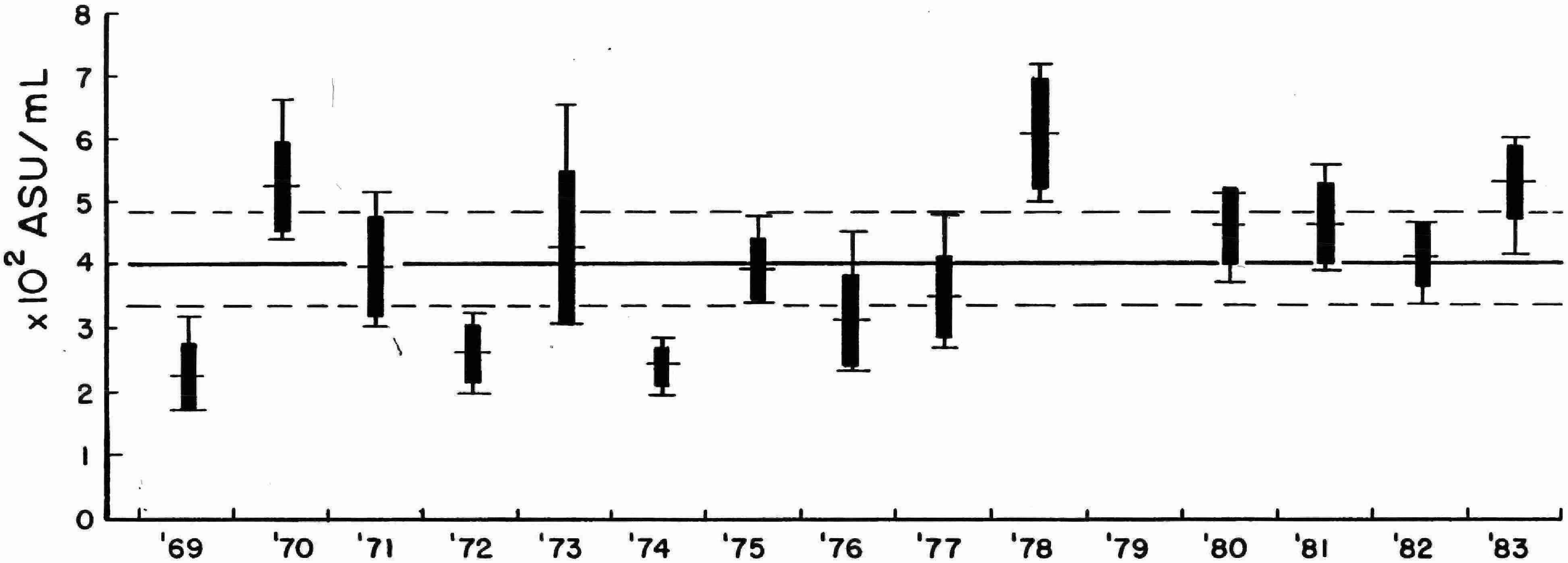
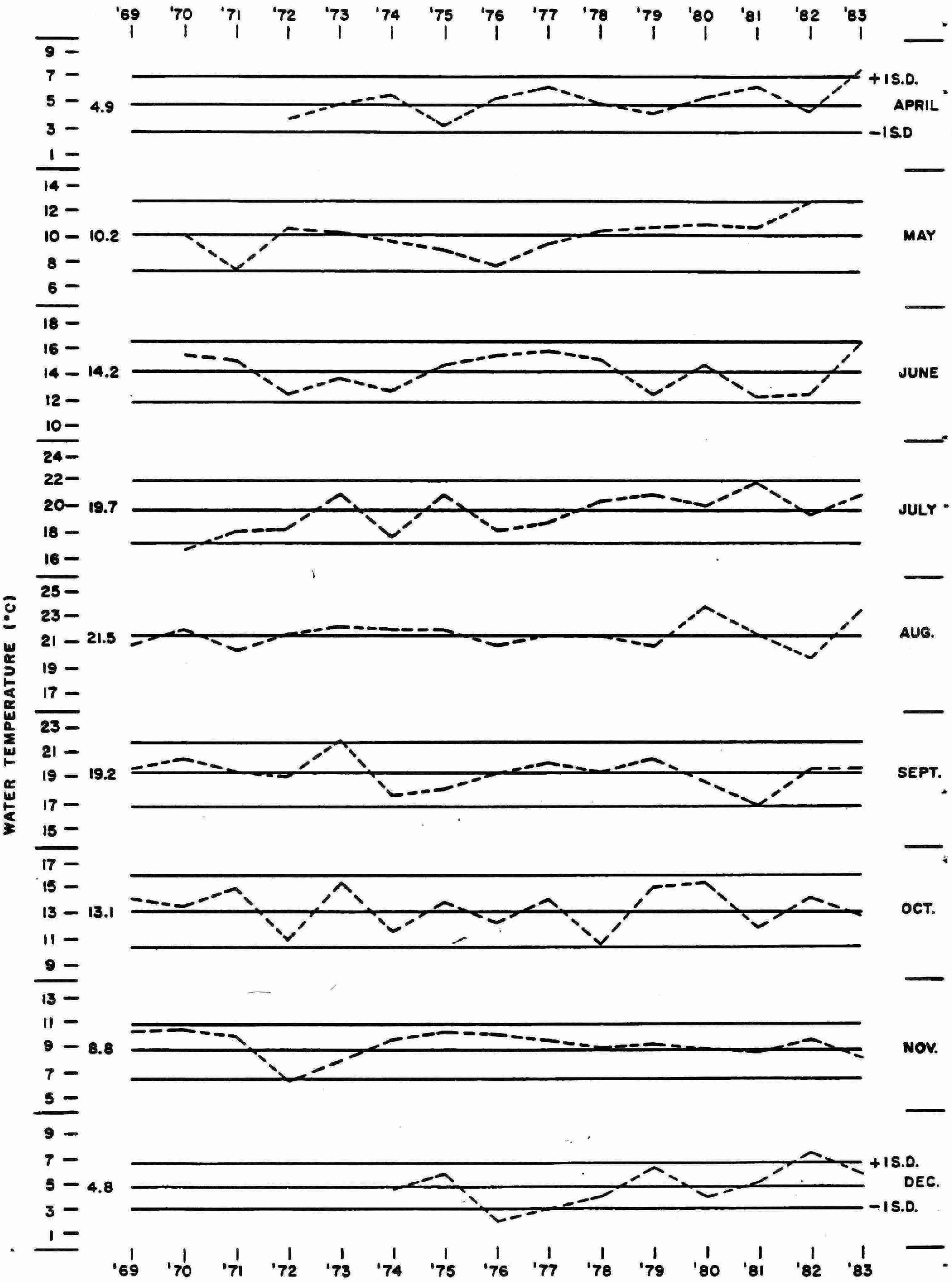


FIGURE 4



'69 '70 '71 '72 '73 '74 '75 '76 '77 '78 '79 '80 '81 '82 '83
WATER TEMPERATURE (°C)
+1S.D.
APRIL
-1S.D
4.9
MAY
10.2
JUNE
14.2
JULY
19.7
AUG.
21.5
SEPT.
19.2
OCT.
13.1
NOV.
8.8
+1S.D.
DEC.
-1S.D.
4.8

FIGURE 5

Table 1. Nanticoke Water Sampling and Temperature Profile Stations by location and year from 1969 to 1983.

Station	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83
1. 112	x	x	x	x	x	x	x	x	x	x	T*	x	x	x	x
2. 501	x	x	x	x	x	x	x	x	x	x			x	x	x
3. 518	x	x	x	x	x	x	x	x	x	x			x	x	x
4. 648	x	x	x	x	x	x	x	x	x	x			x	x	x
5. 810	x	x	x	x	x	x	x	x	x	x	T*	x	x	x	x
6. 994	x	x	x	x	x	x	x	x	x	x	T*	x	x	x	x
7. 1016 (5016)	x	x	x	x	x	x	x	x	x	x	T*	x	x	x	x
8. 1008 (5008)	x	x	x	x	x	x	T*	T*	T*	T*	T*	T*		T*	T*
9. 1040 (1276)			x	x	x	x	x	x	x	x	T*	x	T*	T*	T*
10. 1041							x	x	x	x					
11. 1042							x	x	x	x					
12. 1085										x	T*	x	x	x	x
13. 1086										x		T*	T*	T*	T*
14. 1087										x		T*	T*	T*	T*
sample depth m = 1 metre p = photic zone	m	m/p	m/p	p	p	p	p	p	p	p	p	p	p	p	p
Number of sampling dates	16	15	13	14	15	16	15	17	12	11	17	18**	17	18	20

T*-temperature only

**Temp. = 11 dates

Table 2. Summary of annual mean (seasonal) Phytoplankton Biomass at 7 stations, Nanticoke, Lake Erie, 1969-1983. Data converted to mm^3/L using the regression equation developed by Nicholls (Nicholls et al. 1980).

Year	Reported By	Annual Mean Algal A.S.U./mL±1 S.D.	Biomass mm^3/L	Dominant) 1st, 2nd Taxa) 3rd, 4th
1969)	M. Michalski 1972	224 ± 51.76	0.59	Fragilaria, Cryptomonas Rhodomonas, Ceratium
1970)		524 ± 70.48	1.21	Fragilaria, Cryptomonas, Rhodomonas, Aphanothece
1971)		400 ± 78.53	0.96	Fragilaria, Cryptomonas, Rhodomonas, Oocystis
1972)	G.J. Hopkins 1975	260 ± 44.86	0.66	Cryptomonas, Rhodomonas, Fragilaria, Ceratium
1973)		426 ±122.39	1.01	Fragilaria, Rhodomonas, Cryptomonas, Greens
1974)		239 ± 33.43	0.62	Fragilaria, Cryptomonas, Rhodomonas, Aphanothece
1975)	G.J. Hopkins 1979	390 ± 52.41	0.93	Fragilaria, Cryptomonas, Rhodomonas, Greens
1976)		311 ± 73.17	0.77	Fragilaria, Cryptomonas, Rhodomonas, Greens
1977)		352 ± 66.16	0.86	Fragilaria, Cryptomonas, Rhodomonas, Ceratium
1978)		606 ± 82.78	1.39	Fragilaria, Cryptomonas Rhodomonas, Aphanothece
1979	No data			
1980)	Unpublished	467 ± 66.28	1.10	Stephanodiscus, Fragilaria Rhodomonas, Cryptomonas
1981)		467 ± 65.03	1.10	Fragilaria, Stephanodiscus, Chrysophyceae, Cryptomonas
1982)		418 ± 50.00	0.90	Stephanodiscus, Fragilaria, Rhodomonas, Cryptomonas
1983)		535 ± 59.28	1.24	Stephanodiscus, Fragilaria, Greens, Rhodomonas
14 Year Mean		401 ±115.12	0.96	

Table 3: Phytoplankton data for Nanticoke, Lake Erie, 1969-1983. Mean biomass for seven stations by week. All values expressed as A.S.U. per ml.

		Apr.				May				June				July					Aug.				Sept.				Oct.				Nov				Dec		
Year Wk.No.		16		18		20		22		24		26		28		30		32		34		36		38		40		42									
1969			254		397		164		115		147		99		374		220		220		389		146		198		230		233		283				160		
1970					540		457		196		396		316		378		683		586		927		899		1377		207		403		273		242				
1971						481				279		270		207		474		626		553		462		340		565		341		230		373					
1972	150		278		427				296		246		178		126		155				369		366		284		277		220				280				
1973						422		310		717		422		237		409		1083		212		202		238		512		366		279		299		524			
1974			171		77		214		230		154		139		176		675		249		124		348		351		393		239		154				144		
1975				247		239		340		334				231				414		493		478		638		529			509	392			348	260			
1976		348		474				144		114		62		297		307		232		384		807		351		343		203		334		359					247
1977			649		320			270			404			187			374			461			432			457			418					122			159
1978			328			471			1012			398			528				528		1231			584			684			556							344
1979	No data																																				
1980	451		704		484		542		483		284		453		230		214	393			667		518		523	373		538			555		496		483		
1981			534		322		541		756		419		212		339	602			422		535		799		457		498		492		409		383		223		
1982	405		472		387		473		581		561		94	309		380			338		639		278		219		443		747		407		372		413		
1983	440		516		460		592		743		289		367		316		348		437		1070		727		689		478	773			678		537		311		
14 year Monthly x ± 1 S.D.		401 ±159.82				378 ±139.00				381 ±231.95					313 ±152.74				522 ±281.49				489 ±275.08				423 ±155.55					375 ±126.02			283 ±135.06		

Table 4: Taxonomic Composition of phytoplankton at seven stations, Nanticoke, Lake Erie 1969-1983.

CYANOPHYCEAE

Anabaena flos-aquae (Lyngb.) De Brebisson
A. limnetica G.M. Smith
Anabaena sp.
Aphanizomenon flos-aquae (L.) Ralfs
Aphanizomenon sp.
Aphanocapsa elachista West and West
Aphanocapsa sp.
Aphanothece clathrata West and West
A. nidulans P. Richter
Aphanothece sp.
Arthrospira sp.
Calothrix sp.
Chroococcus limneticus Lemm.
C. minutus (Kutz.) Naegeli
Chroococcus sp.
Coelosphaerium sp.
Dactylococcopsis sp.
Gloeocapsa sp.
Gloeothece sp.
Gomphosphaeria aponina Kutz
G. lacustris Chodat
Gomphosphaeria sp.
Lyngbya limnetica Lemm.
Lyngbya sp.
Merismopedia glauca (Ehrenb.) Naegeli
M. tenuissima Lemm.
Merismopedia sp.
Microcystis aeruginosa Kutz.
Microcystis sp.
Oscillatoria sp.
Phormidium sp.
Rhabdoderma sp.

DINOPHYCEAE

Ceratium hirundinella (O. Mull.) Shrank
Ceratium sp.
Diplopsalsis acuta Entz
Glenodinium quadridens (Stein) Schiller
Gymnodinium palustre Schilling
Gymnodinium sp.
Peridiniopsis sp.
Peridinium sp.

CRYPTOPHYCEAE

Chroomonas sp.
Cryptomonas erosa Ehr.
C. ovata Ehr.
Cryptomonas sp.
Katablepharis sp.
Rhodomonas lacustris Pascher et Ruttner
Rhodomonas sp.

EUGLENOPHYCEAE

Euglena sp.
Phacus sp.
Trachelomonas sp.

CHRYSOPHYCEAE

Bicoeca sp.
Bitrichia skujai Nauwerck = Chrysolykos skujai Nauwerck
Bitrichia sp.
Chromulina erkensis Skuja
Chromulina sp.
Chrysochromulina parva Lackey
Chrysolykos planktonicus Mack
Chrysolykos skujai Nauwerck
Chrysosphaerella coronacircumspina D.E. and M.G. Wujek
Chrysosphaerella sp.
Desmarella spp.
Dinobryon bavaricum Imhof

CHRYSOPHYCEAE (continued)

D. crenulatum W and G.S. West
D. divergens Imhof
D. pediforme (Lemm.) Steinecke
D. sertularia Ehr.
D. sociale Ehr.
Dinobryon spp.
Diplosigopsis siderotheca Skuja
Epipyxis sp.
Kephyrion sp.
Mallomonas sp.
Monochrysis sp.
Ochromonas sp.
Salpingoeca sp.
Stelexomonas sp.
Synura uvella Ehr.
Synura sp.
Uroglenopsis sp. = *Uroglena* sp.

CHLOROPHYCEAE

Actinastrum sp
Ankistrodesmus falcatus (Corda) Ralfs
Ankistrodesmus sp.
Arthrodesmus sp.
Botryococcus sp.
Carteria sp.
Characium limneticum Lemm.
Characium sp.
Chlamydomonas Bergii Nyg.
C. Dinobryoni G.M. Smith
C. epiphytica G.M. Smith
Chlamydomonas sp.
Chlorella sp.
Chlorococcum sp.
Chlorogonium sp.
Chodatella ciliata (Lag.) Lemm.
C. quadriseta Lemm.

CHLOROPHYCEAE (continued)

C. subsalsa Lemm.

Chodatella sp.

Closteriopsis longissima Lemm.

Closteriopsis sp.

Closterium acerosum (Schrank) Ehr.

C. parvulum Naeg.

Closterium sp.

Coelastrum microporum A. Braun

Coelastrum sp.

Cosmarium obtusatum Schmidle

Cosmarium sp.

Crucigenia irregularis Wille

C. rectangularis (A. Braun) Gay

C. tetrapedia (Kirch.) West and West

Crucigenia sp.

Desmidium sp.

Dictyosphaerium Ehrenbergianum Naeg.

D. pulchellum Wood

Dictyosphaerium sp.

Elakatothrix gelatinosa Wille

Elakatothrix sp.

Euastrum sp.

Eudorina sp.

Franceia Droescheri (Lemm.) G.M. Smith

Franceia sp.

Geminella sp.

Gloeocystis gigas (Kutz.) Lagerheim

Gloeocystis sp.

Golenkinia paucispina West and West

G. radiata (Chod.) Wille

Golenkinia sp.

Gonium sociale (Duj.) Warming

Gonium sp.

Gyromitus sp.

Kirchneriella lunaris (Kirch.) Moebius

K. obesa (W. West) Schmidle

CHLOROPHYCEAE (continued)

Kirchneriella sp.
Koliella sp.
Micractinium sp.
Monoraphidium sp.
Mougeotia sp.
Nephrochlamys sp.
Nephrocytium lunatum W. West
Nephrocytium sp.
Oedogonium sp.
Oocystis Borgei Snow
Oocystis sp.
Ophiocytium sp.
Pandorina sp.
Pediastrum Boryanum (Turp.) Meneghini
P. duplex Meyen
P. simplex (Meyen) Lemm.
Pediastrum sp.
Planktonema sp.
Polytoma sp.
Quadrigula Chodatii (Tan.-Ful.) G.M. Smith
Quadrigula sp.
Scenedesmus arcuatus Lemm.
S. bijuga (Turp.) Lagerheim
S. bijuga var. alternans (Reinsch) Hansgirg
S. denticulatus Lagerheim
S. dimorphus (Turp.) Kutz.
S. incrassatulus Bohlin
S. opoliensis P. Richter
S. quadricauda (Turp.) de Brebisson
S. spinosus Chodat
Scenedesmus sp.
Schizochlamys sp.
Schroederia anchora G.M. Smith
S. Judayi G.M. Smith
S. setigera (Schroed.) Lemm.
Schroederia sp.

CHLOROPHYCEAE (continued)

Selenastrum minutum (Naeg.) Collins
Selenastrum sp.
Sorastrum sp.
Sphaerocystis Schroeteri Chodat
Sphaerocystis sp.
Spirogyra sp.
Spondylosium sp.
Staurastrum sp.
Tetraedron caudatum (Corda) Hansgirg
T. minimum (A. Braun) Hansgirg
T. pentaedricum West and West
T. regulare Kutz.
Tetraedron sp.
Tetrastrum staurogeniaeforme (Schroeder) Lemm.
Tetrastrum sp.
Treubaria setigerum (Archer) G.M. Smith
Treubaria sp.
Ulothrix sp.

BACILLARIOPHYCEAE

Achnanthes sp.
Amphora ovalis Kutz.
Asterionella formosa Hass.
A. formosa var. acaroides Lemm.
Asterionella sp.
Campylodiscus sp.
Cocconeis pediculus Ehr.
C. placentula Ehr.
Cocconeis sp.
Cyclotella Meneghiniana Kutz.
C. michiganiana Skv.
C. stelligera Cl. and Grun.
C. striata (Kutz.) Grun.
Cyclotella sp.
Cymatopleura angulata Grev.
Cymatopleura sp.

BACILLARIOPHYCEAE (continued)

Cymbella turgida Greg.
Cymbella sp.
Diatoma elongatum (Lyngb.) Ag.
D. vulgare Bory
Diatoma sp.
Epithemia sp.
Eunotia sp.
Fragilaria capucina Desm.
F. crotonensis Kitt.
Fragilaria sp.
Gomphonema sp.
Gyrosigma sciotense (Sulliv. and Wormley) Cl.
Gyrosigma sp.
Melosira binderana Kutz. = Stephanodiscus binderanus
M. granulata (Ehr.) Ralfs
Melosira sp.
Navicula notha Wallace
N. tripunctata (O.F. Mull.) Bory
Navicula spp.
Nitzschia acicularis (Kutz.) W. Smith
N. dissipata (Kutz.) Grun
N. fonticola Grun
N. Hantzschiana Rabh.
N. Kutzingiana Hilse.
N. Lorenziana Grun
N. palea (Kutz.) W. Smith
N. paleacea Grun
N. sigma (Kutz.) W. Smith
N. sigmoidea (Ehr.) W. Smith
N. tryblionella Hantzsch.
Nitzschia spp.
Rhizosolenia eriensis H.L. Smith
Rhizosolenia sp.
Rhoicosphenia curvata (Kutz.) Grun
Rhoicosphenia sp.
Stephanodiscus alpinus Hust.

BACILLARIOPHYCEAE (continued)

S. astrea (Ehr.) Grun

S. Hantzschii Grun

S. invisitatus Hahn and Hellerman

S. niagarae Ehr.

Stephanodiscus sp.

Surirella biseriata Breb. and Godey

Surirella sp.

Synedra acus Kutz.

S. nana Meist.

S. rumpens Kutz.

S. tenera W. Smith

Synedra sp.

Tabellaria fenestrata (Lyngb.) Kutz.

Tabellaria sp.

Table 5. Temperature Data. Nanticoke, Lake Erie, 1969-1983. Mean temperature (°C) for seven stations by date.

Year			Apr.				May				June				July				August				Sept.				Oct.				Nov.				Dec.	
Year Wk.No.		16		18		20		22		24		26		28		30		32		34		36		38		40		42		44		46		48		50
1969																			20.7						19.5		17.0		10.7		10.3					
1970							10.3		14.3		16.3		15.0		18.6				22.5		21.5		21.0		19.6		13.2		13.3		12.8	8.1				
1971						7.7				14.0		16.0		20.5		16.1		21.5		19.4	20.4		21.1		17.4		13.8		15.5		9.8					
1972		2.4		5.3		7.9		13.2		12.1		12.6		16.2		20.6					21.6		19.9		17.9		12.1		9.4		6.7					
1973						8.3	10.5	12.3	12.8	12.4	12.5	17.0		20.2		22.1		22.0		22.3		24.9		18.6		17.2		15.4	12.4			8.0	8.0			
1974			5.5		6.4		12.9		12.4		13.0		15.2		17.7		20.5		21.5		22.7		20.0		15.2		12.2		10.7		10.6		8.1		4.5	
1975		2.2	2.2	5.5		9.2		9.0		13.0	11.8	18.9		23.7		18.7		22.0		22.2		20.9		17.6	15.4		14.3		13.0		11.5		8.9			5.8
1976		3.8		6.7		6.4		9.4		14.1		16.5		17.8		19.0		21.0		20.5		20.0		18.1		15.5			8.6			6.1	4.2			1.7
1977			5.9		6.7		10.6	11.4		13.4		17.7		18.3			19.3		22.2		20.7			19.9			16.6		11.1		11.4		7.4			2.7
1978		4.9			6.2	8.6		17.2	12.6			17.3		19.1	21.9				22.2	20.8		21.8		18.6	17.4			11.4	9.7			9.0				3.8
1979	1.3			7.0	11.3			10.5		12.6				19.6		22.2		21.4		20.1		21.6		18.9		18.2				9.5		8.6		7.8		4.5
1980	3.5		7.1		9.3		12.7				14.8		17.3		20.3		23.0				23.6					15.1									3.7	
1981			5.8		8.9		12.4		10.1		14.9		22.3		22.1	21.9			20.1		22.9		19.7		14.0		12.4		11.1		9.6		7.1		5.0	
1982	2.8		5.8		12.0		13.0		13.0		12.2		18.1	19.2		21.6			20.9		18.9		21.6		17.1		16.8		10.9		9.9		9.0		7.3	
1983	6.0		8.6		9.9		11.0		16.4		16.4		18.7		21.9		22.6		23.2		23.8		20.1		18.7		13.7	11.5			9.2		7.3		5.6	

15 Year	Apr.	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Monthly	4.9	10.2	14.2	19.7	21.5	19.2	13.1	8.8	4.8
x ± 1 S.D.	2.00	2.51	2.16	2.31	2.31	2.27	2.55	1.88	1.83

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